REMARKS

Claims 1-19 are presently pending in this application, all of which stand finally rejected under 35 U.S.C. §103(a) as allegedly being unpatentable over Kamegawa, *et al.* (U.S. Patent No. 5,710,718) in view of Tang (U.S. Patent No 6,061,673).

Via the foregoing amendments, independent claims 1, 10 and 15 are amended to delete the term "non-linear" and to change the phrase "neural conversion system" to --neural network conversion system--. In addition, the expression "which have a [or the] plurality of extremums" is added thereto. Additional claim amendments are also made consistent with those mentioned above.

Kamegawa '718 is the U.S. counterpart of WO94/16877, which is described in the "Background" section of the present application. As described in the "Background" section of the present application, Kamegawa '718 relates to a single extremum, while the present invention relates to a plurality of extremums.

To signify the plurality of extremums, the term "non-linear" is used in the present application. However, to make the differences between the present invention and Kamegawa more readily apparent, the term "non-linear" appearing in the claims and the specification is hereby deleted and the expression "the plurality of extremums" is used instead.

As explained in the "Background" section of the instant application, when an objective function is simple, a design space could be compared to a mountain with one peak (i.e., a single

extremum) as shown in Fig. 8, and therefore, the approach as taught by Kamegawa, i.e., an optimization approach based on mathematical programming, may be sufficient.

However, when the objection function becomes complex, the design space has many peaks (i.e., a plurality of extremums) as shown in Fig. 9. In this circumstance, an optimal solution cannot be obtained by the optimization approach of Kamegawa based on mathematical programming.

The present invention was made in view of these deficiencies of Kamegawa, and Kamegawa neither teaches nor suggests the invention as now more clearly recited. Moreover, the Examiner's secondary reference, i.e., Tang, fails to supply the deficiencies of Kamegawa.

Finally, for the Examiner's information, Applicant wishes to bring to the Examiner's attention the fact that counterpart applications of the present application filed in the United Kingdom, Germany, Italy and Spain have all been allowed. A copy of the allowed claims in the counterpart EP application (EP 0 937 570 B1) is appended hereto.

In view of the preceding amendments and remarks, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby earnestly solicited. If any points remain in issue that the Examiner feels may be best resolved through a personal or telephonic interview, the Examiner is kindly requested to contact the undersigned attorney at the local telephone number listed below.

The USPTO is directed and authorized to charge all required fees (with the exception of the Issue/Publication Fees) to our Deposit Account No. 19-4880. Please also credit any over-payments to said Deposit Account.

Respectfully submitted,

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(54) METHOD OF DESIGNING TIRE, OPTIMIZATION ANALYZER AND STORAGE MEDIUM ON WHICH OPTIMIZATION ANALYSIS PROGRAM IS RECORDED

VERFAHREN ZUM ENTWERFEN VON REIFEN, OPTIMIERUNGSANALYSEREINRICHTUNG UND SPEICHERMEDIUM ZUR AUFNAHME DES OPTIMIERUNGSANALYSEPROGRAMMS

METHODE DE CONCEPTION DE PNEUMATIQUE, MODULE ANALYSEUR D'OPTIMISATION ET SUPPORT DE MEMORISATION SUR LEQUEL EST ENREGISTRE LE PROGRAMME D'ANALYSE D'OPTIMISATION

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INDUSTRIAL APPLICABILITY

[0136] As described above, the tire design method, the optimization analyzing apparatus, and the storage medium in which the optimization analyzing program is stored according to the present invention have usability with respect to design of the shape, structure, and pattern of a tire, in producing a tire.

Claims

1. A tire design method comprising the steps of:

   (a) determining a conversion system in which a non-linear correspondence between design parameters of a tire, which represent any one of a cross-sectional configuration of the tire including an internal structure and a structure of the tire, and performances of the tire is established by means of a neural network which learns or has learnt said correspondance;
   (b) determining an objective function which expresses said performances of the tire and setting a constraint condition which constrains an allowable range of at least one of said performances of the tire and manufacturing conditions of the tire; and
   (c) determining a design parameter of the tire, which gives an optimum value of an objective function, based on said objective function and said constraint condition by using the conversion system determined in said step (a) to design the tire based on the design parameter of the tire.

2. A tire design method according to claim 1, wherein said step (c) comprises the steps of: defining the design parameter of the tire as a design variable; obtaining a value of the design variable, which gives the optimum value of the objective function, by using the conversion system determined in said step (a) while considering the constraint condition; and designing the tire based on the design variable which gives the optimum value of the objective function.

3. A tire design method according to claim 2, wherein said step (c) comprises: predicting an amount of change in the design variable which gives the optimum value of the objective function while considering the constraint condition based on a sensitivity of the objective function which is a ratio of an amount of change in the objective function to a unit amount of change in the design variable and a sensitivity of the constraint condition which is a ratio of an amount of change in the constraint condition to a unit amount of change in the design variable; calculating a value of the objective function when the design variable is changed to correspond to a predicted amount and a value of the constraint condition when the design variable is changed to correspond to a predicted amount; and based on the predicted and calculated values, obtaining a value of the design variable, which gives the optimum value of the objective function, by using the conversion system determined in said step (a) while considering the constraint condition.

4. A tire design method according to claim 1, wherein said step (c) comprises the steps of: (d) selecting, as a design variable, one of the design parameters of the tire included in the conversion system determined in said step (a); (e) changing a value of the design variable selected in the conversion system determined in said step (a) until the optimum value of the objective function is given by using the conversion system determined in said step (a) while considering the constraint condition; and (f) designing the tire based on the design parameter of the tire obtained by the design variable which gives the optimum value of the objective function.

5. A tire design method according to claim 4, wherein said step (b) comprises the step of determining a constraint condition which constrains an allowable range of at least one of tire performances other than said determined objective function and the design parameters of the tire.

6. A tire design method according to claim 4 or 5, wherein said step (e) comprises: predicting an amount of change in the design variable which gives the optimum value of the objective function while considering the constraint condition based on a sensitivity of the objective function which is a ratio of an amount of change in the objective function to a unit amount of change in the design variable and a sensitivity of the constraint condition which is a ratio of an amount of change in the constraint condition to a unit amount of change in the design variable; calculating a value of the objective function when the design variable is changed to correspond to a predicted amount and a value of the constraint condition when the design variable is changed to correspond to a predicted amount; and based on the predicted and calculated values, changing a value of the design variable to be selected until the

optimum value of the objective function is given by using the conversion system determined in said step (a) while considering the constraint condition.

7. A tire design method according to claim 1, wherein said step (c) comprises the steps of: defining the design parameters of the tire in the conversion system determined in said step (a) as base models to determine a group for selection comprising a plurality of base models; determining said objective function, a design variable, a constraint condition and an adaptive function which can be evaluated from the objective function for each base model of the group for selection; selecting two base models from the groups for selection; effecting at least one of producing new base models by intersecting the design variables of the two base models at a predetermined probability with each other and producing new base models by modifying in part the design variables of at least one of the two base models; obtaining an objective function, a constraint condition, and an adaptive function of the base models using the conversion system determined in said step (a) by changing the design variable; storing the base models whose design variables have been changed and base models whose design variables have not been changed; repeating the storing step until the number of the stored base models reaches a predetermined number; determining whether a new group comprising the stored base models of the predetermined number satisfies a predetermined convergence condition; wherein if not, the above steps are repeated until with the new group defined as the group for selection the group for selection defined satisfies the predetermined convergence condition; and if the predetermined convergence condition is satisfied, designing a tire based on the design parameters of the tire obtained by the design variable, which gives the optimum value of the objective function, among the predetermined number of the stored base models by using the conversion system determined in said step (a) while considering the constraint condition.

8. A tire design method according to any one of claims 1 to 7, wherein in said step (a), said conversion system is constructed with data in a multi-layered feed forward type neural network which has learned so as to convert the design parameters of the tire to performances thereof.

9. A tire which is formed according to design parameters designed by a tire design method according to any one of claims 1 to 8.

10. An optimization analyzing apparatus comprising:

conversion system calculating means (32) for obtaining a non-linear corresponding relation between design parameters of a tire and performances of the tire by means of a neural network which learns or has learnt said corresponding relation,
input means (42) for inputting an objective function and a constraint condition as optimization items by determining the objective function which expresses the performances of the tire and also by determining the constraint condition which constrains an allowable range of at least one of the performances of the tire and manufacturing conditions of the tire; and
optimization calculation means (34) for obtaining a design parameter of the tire which gives an optimum value of the objective function based on the optimization items inputted by said input means using said conversion system calculation means.

11. An optimization analyzing apparatus according to claim 10, wherein said conversion system calculation means is provided to obtain a non-linear corresponding relation between, on the one hand, the design parameters of the tire and a condition to be applied to the tire, and on the other hand, the performances of the tire.

12. An optimization analyzing apparatus according to claim 10 or 11, wherein said optimization calculation means comprises: selection means which selects one of the design parameters of the tire included in said conversion system calculation means as a design variable; changing means for changing a value of the design variable selected from said conversion system calculation means until the optimum value of the objective function is given, while considering the constraint condition; optimum value calculation means for calculating a value of the design variable until the optimum value of the objective function is given by using said conversion system calculation means; and design means for designing a tire based on the design parameter obtained by the design variable which gives the optimum value of the objective function.

13. An optimization analyzing apparatus according to claim 10 or 11, wherein said optimization calculation means comprises the steps of: defining the design parameters of the tire in the corresponding relation determined in said conversion system calculation means as base models to determine a group for selection composed of a plurality

of base models; determining said objective function, a design variable, a constraint condition, and an adaptive function which can be evaluated from the objective function for each base model in the group for selection; selecting two base models from the group for selection; effecting at least one of producing new base models by intersecting the design variables of the selected two base models at a predetermined probability with each other and producing new base models by modifying in part the design variables of at least one of the two base models; obtaining an objective function, a constraint condition, and an adaptive function of the base models which have been produced using said conversion system calculation means by changing a design variable; storing the base model whose design variables have been changed and a base model whose design variables have not been changed; repeating the storing step until the number of the stored base models reaches a predetermined number; determining whether a new group comprising stored base models of the predetermined number satisfy a predetermined convergence condition; wherein if not, the new group is defined as the group for selection and the above steps are repeated until the group for selection defined satisfies the predetermined convergence condition; and if the predetermined convergence condition is satisfied, designing a tire based on a design parameter of the tire obtained by the design variable, which gives the optimum value of the objective function, among the predetermined number of the stored base models by using said conversion system calculation means while considering the constraint condition.

14. An optimization analyzing apparatus according to any one of claims 10 to 13, wherein said conversion system calculation means is a multi-layered feed forward type neural network which has learned so as to convert the design parameters of the tire to the performances thereof.

15. A recording medium having a recorded optimization analyzing program for design of a tire executed by a computer, wherein the optimization analyzing program is provided to: determine a non-linear corresponding relation between design parameters of a tire and performances of the tire by means of a neural network which learns or has learnt said corresponding relation; determine an objective function which expresses the performances of the tire and determine a constraint condition which constrains an allowable range of at least one of the performances of the tire and manufacturing conditions of the tire; and obtain a design parameter of the tire, which gives an optimum value of the objective function, based on the determined corresponding relation, the objective function, and the constraint condition to design a tire based on the design parameter of the tire.

16. A recording medium having a recorded optimization analyzing program for design of a tire according to claim 15, wherein the design of a tire based on the design parameters of the tire comprises: selecting, as a design variable, one of the design parameters of the tire included in the determined corresponding relation based on the determined corresponding relation, the objective function, and the constraint condition; changing a value of the design variable selected from the determined corresponding relation until the optimum value of the objective function is given while considering the constraint condition; and designing the tire based on the design parameter of the tire obtained by the design variable which gives the optimum value of the objective function.

17. A recording medium having a recorded optimization analyzing program for design of a tire according to claim 16, wherein the constraint condition constrains an allowable range of at least one of the performances of the tire other than the determined objective function and the design parameters of the tire.

18. A recording medium having a recorded optimization analyzing program for design of a tire according to claim 16 or 17, wherein the change of the design variable is effected by: predicting an amount of change in the design variable which gives the optimum value of the objective function while considering the constraint condition based on a sensitivity of the objective function which is a ratio of an amount of change in the objective function to a unit amount of change in the design variable and a sensitivity of the constraint condition which is a ratio of an amount of change in the constraint condition to a unit amount of change in the design variable; calculating a value of the objective function when the design variable is changed to correspond to a predicted amount and a value of the constraint condition when the design variable is changed to correspond to a predicted amount; and changing a value of the design variable to be selected based on the predicted and calculated values until the optimum value of the objective function is given while considering the constraint condition.

19. A recording medium having a recorded optimization analyzing program for design of a tire according to any one of claims 16 to 18, wherein the design of a tire based on the design parameter of the tire comprises: defining the design parameters of the tire in the determined corresponding relation as base models to determine a group for selection composed of a plurality of base models; determine said objective function, a design variable, a constraint condition, and an adaptive function which can be evaluated from the objective function for each base model in the group for selection; selecting two base models from the groups for selection; effecting at least one of producing

new base models by intersecting the design variables of the selected two base models at a predetermined probability with each other, and producing new base models by modifying in part the design variables of at least one of the two base models; obtaining an objective function, a constraint condition, and an adaptive function of the base model using said conversion system calculation means by changing design variables; storing the base model whose design variables have been changed and a base model whose design variables have not been changed; repeating the storing step until the number of the stored base models reaches a predetermined number; determine whether a new group comprising the stored base models of the predetermined number satisfies a predetermined convergence condition; wherein if not, the new group is defined as the group for selection and the above steps are repeated until the group for selection defined satisfies the predetermined convergence condition; and if the predetermined convergence condition is satisfied, designing a tire based on the design parameter of the tire obtained by the design variable, which gives the optimum value of the objective function, among the predetermined number of the stored base models by using the corresponding relation while considering the constraint condition.

Patentansprüche

1. Reifenentwurfsverfahren, enthaltend die Schritte:

   (a) Bestimmen eines Umsetzsystems, bei dem eine nichtlineare Entsprechung zwischen Entwurfparametern eines Reifens, zum Repräsentieren einer Querschnittskonfiguration des Reifens einschließlich einer Innenstruktur und einer Struktur des Reifens, und einer Funktion des Reifens etabliert ist, mittels einem neuronalen Netzwerk, das die Entsprechung lernt oder gelernt hat;

   (b) Bestimmen einer Zielfunktion zum Ausdrücken der Funktion des Reifens und zum Festlegen einer Nebenbedingung zum Einschränken eines zulässigen Bereichs von zumindest einer Größe aus den Funktionen des Reifens und den Herstellungsbedingungen des Reifens;

   (c) Bestimmen eines Entwurfsparameters des Reifens, der zu einem optimalen Wert der Zielfunktion führt, auf der Grundlage der Zielfunktion und der Nebenbedingung unter Verwendung des Umsetzsystems, bestimmt in dem Schritt (a) zum Entwerfen des Reifens auf der Grundlage des Entwurfsparameters des Reifens.

2. Reifenentwurfsverfahren nach Anspruch 1, wobei der Schritt (c) die Schritte enthält: Definieren des Entwurfsparameters des Reifens als Entwurfsvariable; Erhalten eines Werts der Entwurfsvariablen, die zu dem optimalen Wert der Zielfunktion führt, unter Verwendung des Umsetzsystems, bestimmt in Schritt (a), während einer Betrachtung der Nebenbedingung; und Entwerfen des Reifens auf der Grundlage der Entwurfsvariablen, die zu dem optimalen Wert der Zielfunktion führt.

3. Reifenentwurfsverfahren nach Anspruch 2, wobei der Schritt (c) enthält: Vorhersagen einer Umfangsänderung der Entwurfvariablen, die zu dem optimalen Wert der Zielfunktion führt, während einem Betrachten der Nebenbedingung auf der Grundlage einer Empfindlichkeit der Zielfunktion, die ein Verhältnis eines Änderungsumfangs der Zielfunktion zu einer Einheitsmenge einer Änderung der Entwurfsvariablen darstellt, sowie einer Empfindlichkeit der Nebenbedingung, die ein Verhältnis eines Änderungsumfangs in der Nebenbedingung gegenüber einer Einheitsänderung der Änderung der Entwurfsvariablen darstellt; Berechnen eines Werts der Zielfunktion, wenn die Entwurfsvariable so geändert wird, dass sie einem vorhergesagten Umfang entspricht, sowie eines Werts der Nebenbedingung, wenn die Entwurfsvariable zum Entsprechen zu einem vorhergesehenen Umfang geändert wird; und auf Grundlage der vorhergesagten berechneten Werte, Erhalten eines Werts der Entwurfsvariablen, der zu einem optimalen Wert der Zielfunktion führt, unter Verwendung des in dem Schritt (a) bestimmen Umsetzsystems bei Betrachtung der Nebenbedingung.

4. Reifenentwurfsverfahren nach Anspruch 1, wobei der Schritt (c) die Schritte enthält: (d) Auswählen, als Entwurfsvariable, an einem der Entwurfsparameter des Reifens, enthalten in dem Umsetzsystem, das in dem Schritt (a) bestimmt wird; (e) Ändern eines Werts der Entwurfsvariablen, die in dem Umsetzsystem ausgewählt ist, das in dem Schritt (a) bestimmt wird, bis der optimale Wert der Zielfunktion gegeben ist, unter Verwendung des in dem Schritt (a) bestimmten Umsetzsystems bei Betrachtung der Nebenbedingung; und (f) Entwerfen des Reifens auf der Grundlage des Entwurfsparameters des Reifens erhalten durch die Entwurfsvariable, die zu dem optimalen Wert der Zielfunktion führt.

5. Reifenentwurfsverfahren nach Anspruch 4, wobei der Schritt (b) den Schritt enthält zum Bestimmung einer Ne-